Wireless Telemetry for Industrial Applications

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Project Description

Wireless Replaces and Augments Wired Systems for:

- **Rotating and Complex Machinery**
- **Sealed Compartments**
- **Geographically Distributed Sites**
- **Cluttered Work Areas**

Critical Issues Remain: EMI, battery life, legacy interfaces, security, robustness, etc.

Solutions Require New Approaches: Spread Spectrum, CDMA, Embedded Intelligence, Smaller Form Factor, power management, etc.

Project Objectives/Goal

- **IOF need(s) addressed by this technology**
  - Ubiquitous Sensing to reduce waste and emissions, improve efficiency, improve raw material utilization.
- **Objectives**
  - Demonstrate Reliable Wireless Telemetry
  - Integrate legacy sensors
  - Demonstrate new wireless sensor capability
  - Establish bounds on integrity - security and robustness
- **Overall goal**
  - Reduce the cost of deploying sensors in IOF facilities.

Technical Risks/Innovation

- **Technical risks**
  - Reducing radio power while maintaining reliable communications in IOF facility harsh environments.
- **Innovation**
  - Providing Direct Sequence (eventually hybrid), Spread Spectrum radio with 63-bit (or longer) spreading codes in robust configuration for reliable deployment with minimal operator intervention, no interference, and long battery life.
- **Advancement of state-of-the-art; over competition**
  - Most commercial systems use frequency hopping which can interfere with plant electronics or use shorter spreading codes that are less robust. Other systems don't support legacy interfaces while providing a path to more advanced wireless networks. Embedded intelligence reduces bandwidth and power required.

Task Performance

Past Technical Milestones

Milestone	Due Date	Completion Date	Comments
Functional Description and Requirements Document	3/30/99	3/30/99	Evolved until 10/99
Architecture Specification	3/30/99	12/30/99	Funding arrived in 10/99
Field Prototype Demo	9/30/00	12/30/00	Funding arrived late
Industry Test bed started	9/30/01	9/30/01	Continue to work with Timken

Progress Toward Performance Goals

- **Highlighted in 1998 National Research Council Report describing goals for industrial wireless networks:**
  - Eliminating interference (assuring reliable communications);
  - Easing deployment of intelligent wireless sensors;
  - Developing reliable networks (robust architectures);
  - Developing remote power (long lasting and reliable);
  - Developing standardized communication protocols

Progress Toward Performance Goals

- **Functional Description and Requirements Document**
  - Numerous requests from IEEE 1451 committee and industry for our report on industry requirements
- **Architecture Specification**
  - Numerous requests for details on open, 1451 compliant, architecture for robust wireless telemetry
  - Open for others to duplicate using identical or functionally equivalent hardware and software
- **Commercial Viability - Now serving on IEEE 1451.5 committee for smart sensor, wireless telemetry**
  - proprietary systems being replaced
  - articles in numerous magazines and invited talks
  - ISA instructor and course developer for wireless course

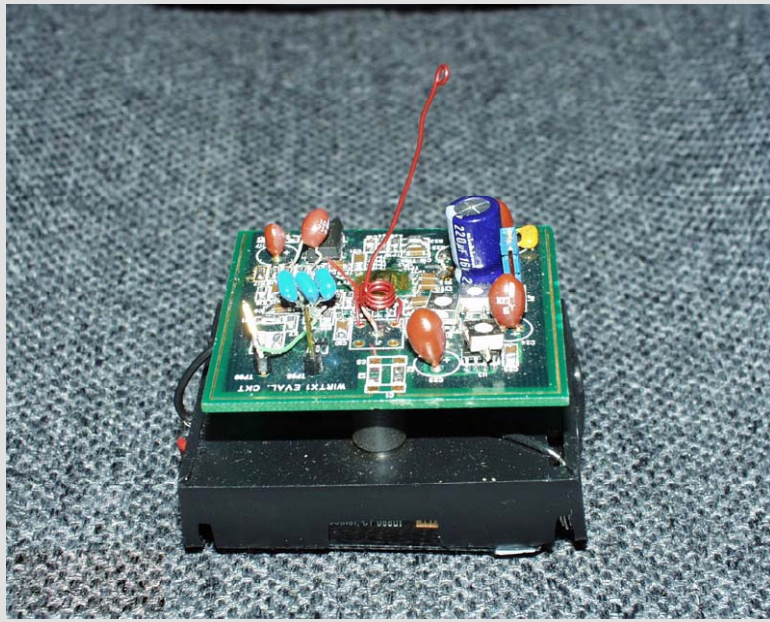
Progress Toward Performance Goals

- **Demonstrations Highlight Performance**
  - USS The Sullivans - First Direct Sequence, Spread Spectrum, transmit only temperature sensor - 8/17/1998 - resulted in industrial partner (Aeptec) contract with Navy
  - Bowater Paper Mill - Demonstrated bidirectional test bed hardware and software at 1/10,000 RF power density of previous technology that had disrupted operation. 12/27/2000
  - Timken - Long-term installation of test bed provides data on failures in low-tech and hi-tech part of the system - 6/2001

We continue to get requests for test installations at industrial sites.

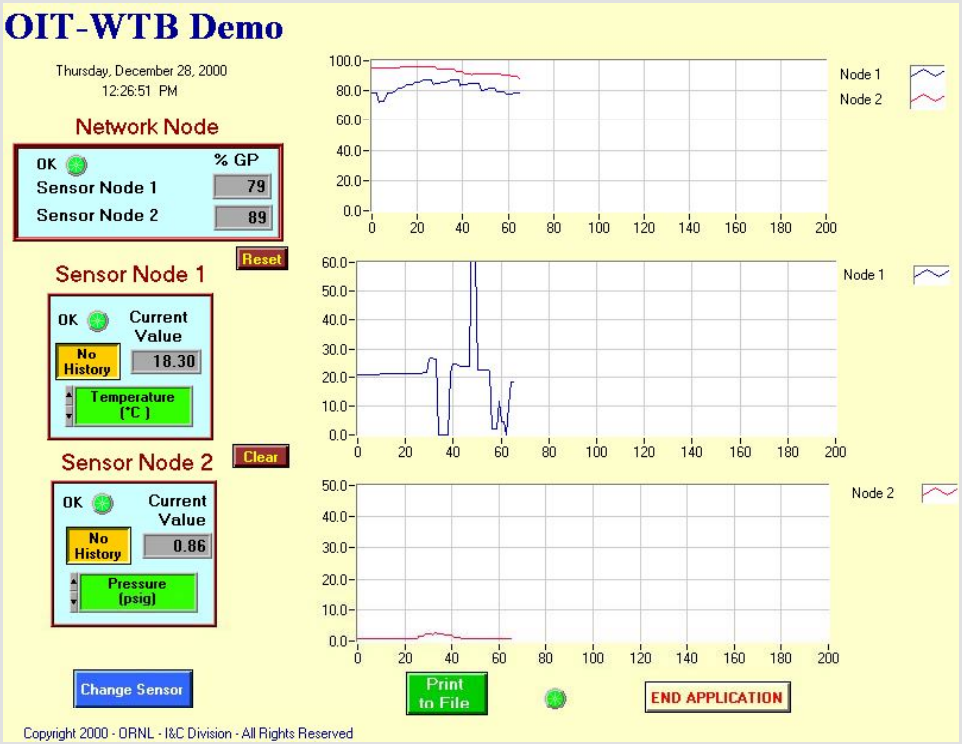
Progress Toward Performance Goals

- **Demo on USS The Sullivans Showed Potential:**
  - **Highly Reflective - multi-path potential failed to compromise connectivity - recorded temperature over 3 decks as well as control room, engine room, generator room.**
  - **Other interferors - IEEE 802.11b wireless network gave no trouble.**
  - **Throughput tracks Bit-error-rate as expected**



Progress Toward Performance Goals

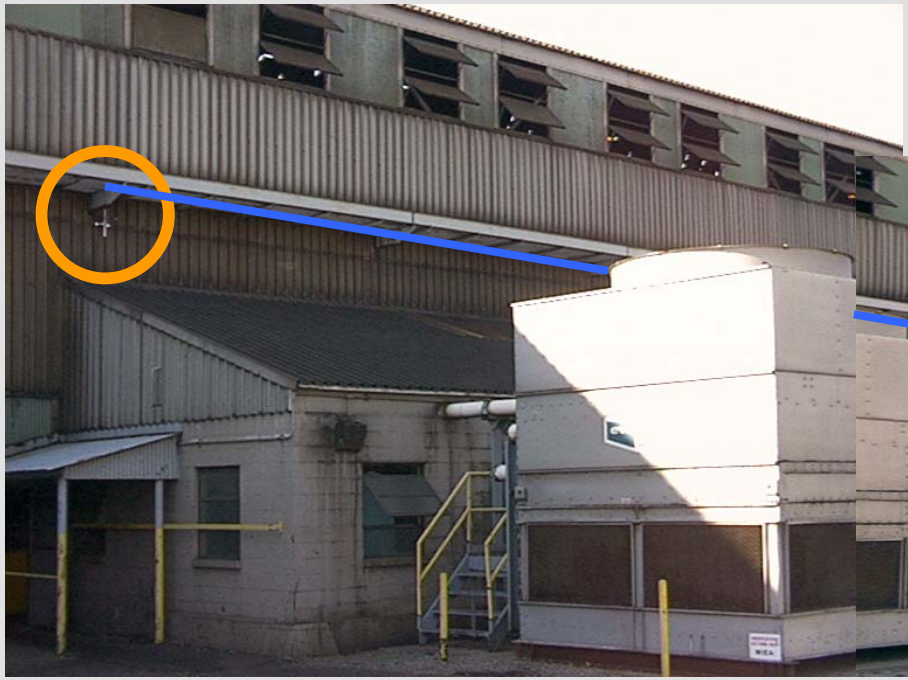
- **Bowater Test Showed Bidirectional Capability**
  - 140 foot connectivity with acceptable BER and throughput
  - saw some storage temperature sensitivity from overnight



Progress Toward Performance Goals

- **Timken Tests Implemented First Repeater Technology**
  - ***Bidirectional, small footprint, Direct Sequence Spread Spectrum***
  - ***Robust packaging, upgraded firmware***
  - ***saw problems with interference from 800-number pager tower***
  - ***seeing problems with micro-controller but no more with radio telemetry***

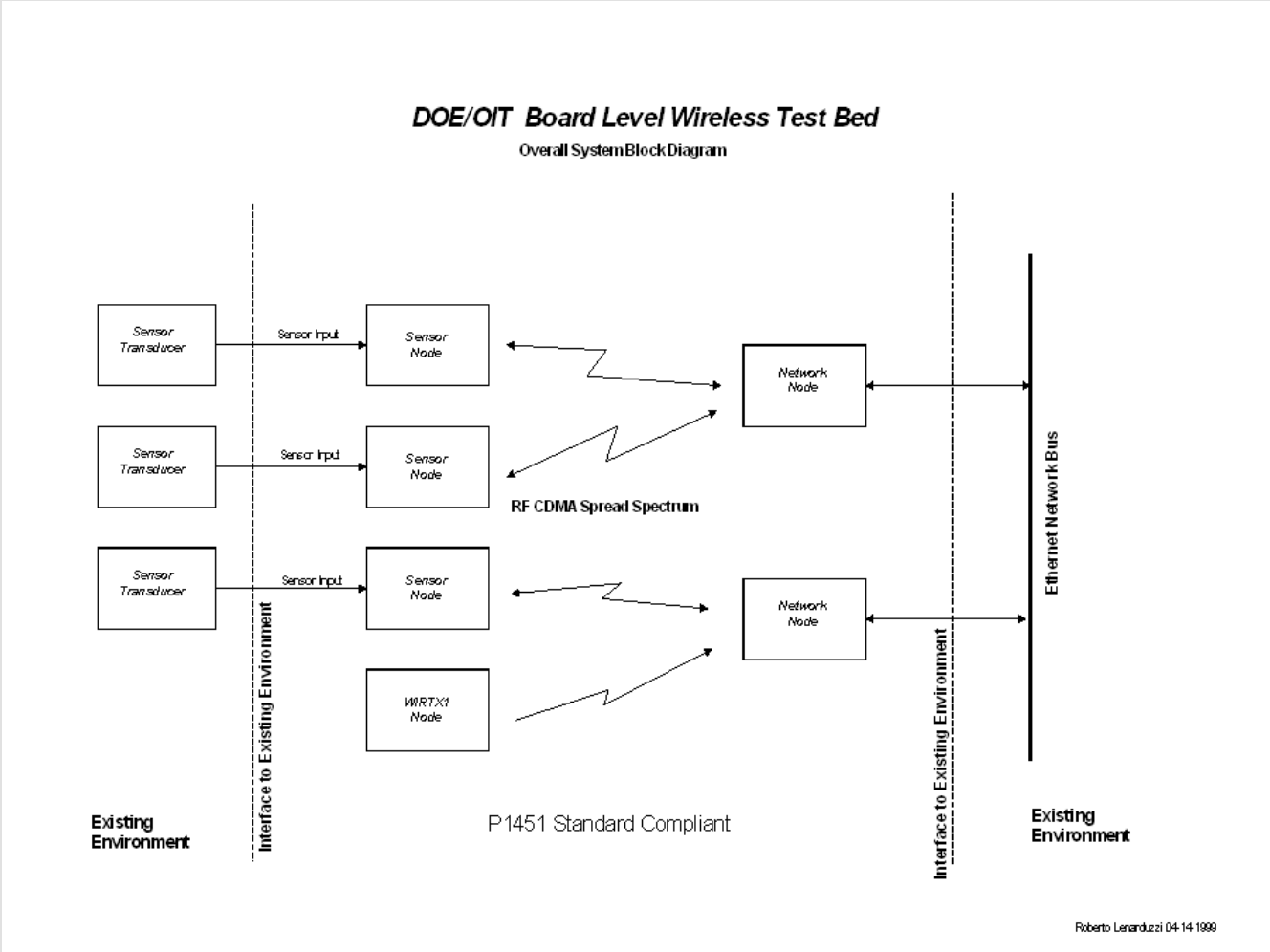
Long-Term Testing Provides Valuable Information



Outside transmitter

Line of Sight to LUT Cabin

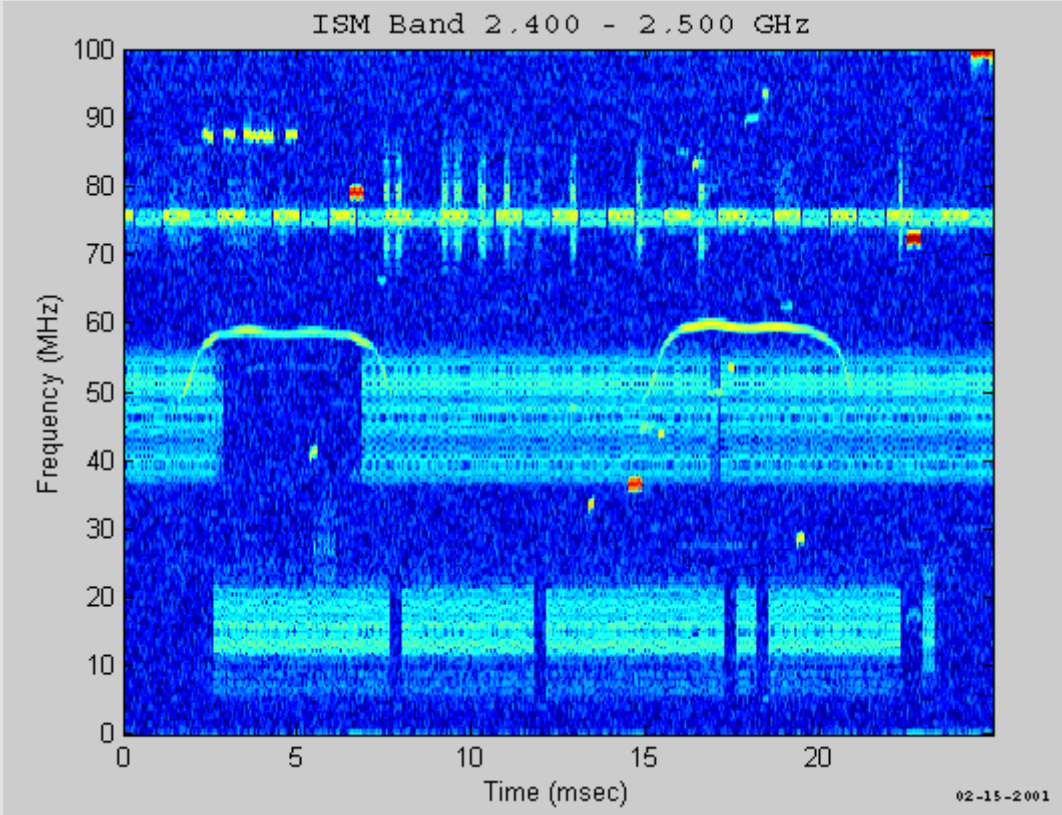
Simple Architecture Supports Legacy Sensors



Current Generation Hardware Designed for Testing

Who/What is in the ISM band?

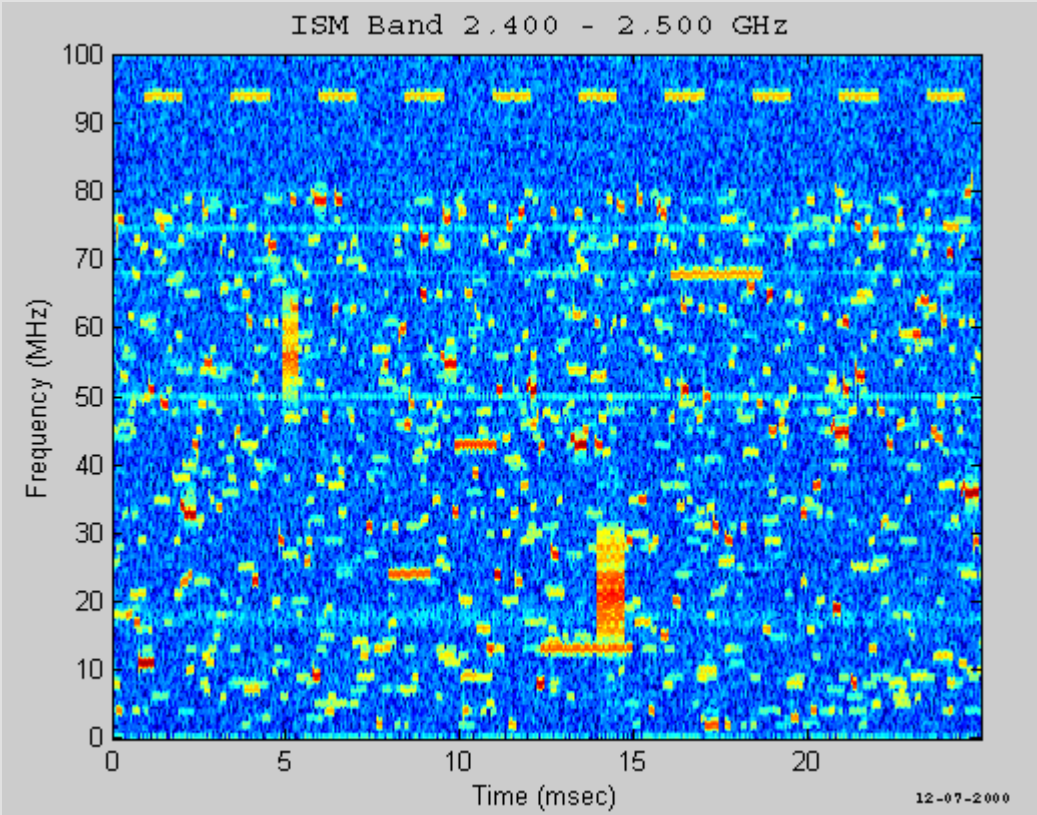
- **WLANs**
- **WPANs™**
- **Industrial**
- **Medical**
- **Scientific**



Both IEEE 802.11b and Bluetooth operate in the same 2.4 GHz ISM Band

What is the WLAN ISM Environment?

- **Pico-nets**
- **Scatter-nets**
- **Proprietary communication and control**
- **802.11b**
- **802.11g**



Communication of devices within a Personal Operating Space

Commercialization

- **Proposed plant tests/deployments, and planned use in IOF manufacturing plant(s)**
  - Timken Steel - long term testbed and beneficial use installation
  - Bowater Paper - next generation planned

- **Commercialization path & partners**
  - Graviton - $M CRADA just ended
  - Tarallax - $M CRADA just starting
  - Robertshaw - long term relationship
  - Aeptec (3e Technologies, Inc) - long term relationship

Nine related patents attract interest from commercial sector.

Performance Merits

- **Improving energy efficiency**
  - How will energy be saved?
    - Maintenance, performance monitoring - reduce unscheduled downtime which reduces scrap
    - Asset Tracking - reduces energy wasted waiting for material, maintenance
    - Process Improvements - lower cost sensing raises process efficiencies in production, in depth view of process - mining the process - not the data base.
  - What are the energy savings (per installed unit and nationwide)?
    - In 1997, the President's advisors on science and technology asserted that wireless sensors could improve efficiency by 10% and reduce emissions by more than 25%.

Performance Merits

- **Reducing emissions**
  - How will emissions be reduced?
    - Process efficiencies - improvements reduce emissions
    - Emission monitoring - early warnings reduce emissions
    - Maintenance - reduces risk of failures
  - What are the reduction levels?
    - S&T advisors to the President estimate 25%

Performance Merits

- **Improving product quality**
  - How will product quality be improved?
    - Process Monitoring and Control - previously unmeasurable (too costly because of motion, distance, clutter, regulations) parameters can now be measured
    - Enabling Technology - provides cheaper, faster, better interfaces for new instrumentation - like LUT at Timken
  - How will this improvement be quantified?
    - Yield improvements - identify quality improvements, waste reduction, reduced cost allows more measurements
    - Value-Chain - compare with potentials available

Performance Merits

- **Improving productivity**
  - How will productivity be improved?
    - Process Monitoring and Control - previously unmeasurable or sampled rather than on-line
    - Reduced downtime - improved maintenance, extended operating life
    - Anticipating needs rather than reacting
  - How will this improvement be quantified?
    - Life tests, operating costs on instrumented lines, uptime measurements.

Performance Merits

- **Reducing costs**
  - How will costs be reduced?
    - Wiring costs - as high as $2000/ft in nuclear power plant and $200/ft (nominal) in chemical plant.
    - Wiring errors - self identifying sensors reduces wiring errors so connectivity is assured
    - Maintenance costs - $4T/yr (worldwide) spent on unneeded replacement of components because no viable measure of status, expected life.
  - What are the cost savings?
    - Depends on process being instrumented

Performance Merits

- **Minimizing waste**
  - How will waste be minimized?
    - Process Monitoring - reduces waste through improved controls, use as trigger (like LUT) improves equipment life
    - Higher Product Yield - fewer rejects
    - Better Customer Satisfaction - fewer returns
  - How will waste minimization be quantified?
    - Equipment life, improved yields

Path Forward

Future Technical Milestones

Milestone	Due Date	Completion Date	Comments
Interim Report	9/30/02		
5.8 GHz components tested	9/30/02		New SiGe technology
Timken Test bed provides reliable connectivity, on-line reports	9/30/02		
Sensor Agent Architecture defined, verified	9/30/02		Embedded intelligence

Path Forward

- **Next steps**
  - SiGe Components Tested - improves bandwidth and reduces interference
  - Timken Testbed - remoted, verified
  - Sensor Agent - architecture defined and verified - reduces bandwidth, battery requirements, increased knowledge/bit transmitted, and improves reliability
  - Hybrid Spread Spectrum - advantages of frequency hopping and direct sequence spread spectrum - patents pending
- **Go/no-go consideration(s)**
  - Timken - robust connectivity demonstration required
  - SiGe - move to 5.8GHz important but not necessary - research!